

Earth Science

Chapter 1

The Nature of Science

BIG Idea Earth scientists use specific methods to investigate Earth and beyond.

Chapter 2

Mapping Our World

BIG Idea Earth scientists use mapping technologies to investigate and describe the world.

CAREERS IN EARTH SCIENCE

Speleologist This speleologist, a scientist who studies caves, descends into a 200-m-deep sinkhole. Speleologists use scientific methods to make maps, collect samples, and make observations of incredible landforms resulting from geologic processes.

WRITING in Earth Science

Visit glencoe.com to learn more about speleologists. What would it be like to explore an undiscovered cave? Write a journal entry about leading a team of speleologists on such an adventure.



**Earth
Science**  **online**

To learn more about speleologists,
visit glencoe.com.

The Nature of Science

BIG Idea Earth scientists use specific methods to investigate Earth and beyond.

1.1 Earth Science

MAIN Idea Earth science encompasses five areas of study: astronomy, meteorology, geology, oceanography, and environmental science.

1.2 Methods of Scientists

MAIN Idea Scientists use scientific methods to structure their experiments and investigations.

1.3 Communication in Science

MAIN Idea Precise communication is crucial for scientists to share their results effectively with each other and with society.

GeoFacts

- The temperature of Earth's core is thought to be as high as 7227°C.
- It is about 6378 km to the center of Earth.
- Seventy percent of Earth's freshwater is contained in glaciers.



Start-Up Activities

LAUNCH Lab

Why is precise communication important?

Have you ever explained something to someone only later to find out that what you thought was a clear explanation was confusing, misleading, or even incorrect? Precise communication is an important skill.

Procedure

1. Read and complete the lab safety form.
2. Obtain an **object** from your teacher. Do not show it to your partner.
3. Write one sentence that accurately describes the object in detail without identifying or naming the object.
4. Give your partner the description and allow him or her a few minutes to identify your object.
5. Now use your partner's description to identify his or her object.

Analysis

1. **Identify** Were you and your partner able to identify each others' objects? Why or why not?
2. **Error Analysis** Work together to rewrite each description in your science journals to make them as accurate as possible.
3. **Compare** Trade the new descriptions with another pair of students. Did this pair of students have an easier time determining the objects than you and your partner did? Why or why not?

FOLDABLESTM Study Organizer

Earth's Systems

Make this Foldable to compare Earth's four main systems.

- ▶ **STEP 1** Fold a sheet of paper in half lengthwise.



- ▶ **STEP 2** Fold the sheet into fourths (fold in half and half again).



- ▶ **STEP 3** Unfold and cut the top flap along the fold lines to make four tabs. Label the tabs *Geosphere*, *Hydrosphere*, *Atmosphere*, and *Biosphere*.



FOLDABLES Use this Foldable with Section 1.1.

As you read this section, summarize Earth's systems and how they interact.

Earth Science^{online}

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 - Interactive Tables
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Section 1.1

Objectives

- ▶ **Compare** the areas of study within Earth science.
- ▶ **Identify** Earth's systems.
- ▶ **Explain** the relationships among Earth's systems.
- ▶ **Explain** why technology is important.

Review Vocabulary

technology: the application of knowledge gained from scientific research to solve society's needs and problems

New Vocabulary

astronomy
meteorology
geology
oceanography
environmental science
geosphere
atmosphere
hydrosphere
biosphere

Earth Science

MAIN Idea Earth science encompasses five areas of study: astronomy, meteorology, geology, oceanography, and environmental science.

Real-World Reading Link From the maps you use when traveling, to the weather report you use when deciding whether or not to carry an umbrella, Earth science is part of your everyday life.

The Scope of Earth Science

The scope of Earth science is vast. This broad field can be broken into five major areas of specialization: astronomy, meteorology, geology, oceanography, and environmental science.

Astronomy The study of objects beyond Earth's atmosphere is called **astronomy**. Prior to the invention of sophisticated instruments, such as the telescope shown in **Figure 1.1**, many astronomers merely described the locations of objects in space in relation to each other. Today, Earth scientists study the universe and everything in it, including galaxies, stars, planets, and other bodies they have identified.

Meteorology The study of the forces and processes that cause the atmosphere to change and produce weather is **meteorology**. Meteorologists also try to forecast the weather and learn how changes in weather over time might affect Earth's climate.

■ **Figure 1.1** The Keck I and Keck II telescopes are part of the Mauna Kea Observatories in Hawaii. One of the Keck telescopes is visible here in its protective dome.



Geology The study of the materials that make up Earth, the processes that form and change these materials, and the history of the planet and its life-forms since its origin is the branch of Earth science known as **geology**. Geologists identify rocks, study glacial movements, interpret clues to Earth's 4.6-billion-year history, and determine how forces change our planet.

Oceanography The study of Earth's oceans, which cover nearly three-fourths of the planet, is called **oceanography**. Oceanographers study the creatures that inhabit salt water, measure different physical and chemical properties of the oceans, and observe various processes in these bodies of water. When oceanographers are conducting field research, they often have to dive into the ocean to gather data, as shown in **Figure 1.2**.

Environmental science The study of the interactions of organisms and their surroundings is called **environmental science**. Environmental scientists study how organisms impact the environment both positively and negatively. The topics an environmental scientist might study include natural resources, pollution, alternative energy sources, and the impact of humans on the atmosphere.

Subspecialties The study of our planet is a broad endeavor, and as such, each of the five major areas of Earth science consists of a variety of subspecialties, some of which are listed in **Table 1.1**.



■ **Figure 1.2** Oceanographers study the life and properties of the ocean.

Investigate What kind of training would this Earth scientist need?

Concepts In Motion

Interactive Table To explore more about the scope of Earth science, visit glencoe.com.

Table 1.1		Subspecialties of Earth Science
Major Area of Study	Subspecialty	Subjects Studied
Astronomy	astrophysics	physics of the universe, including the physical properties of objects found in space
	planetary science	planets of the solar system and the processes that form them
Meteorology	climatology	patterns of weather over a long period of time
	atmospheric chemistry	chemistry of Earth's atmosphere, and the atmospheres of other planets
Geology	paleontology	remains of organisms that once lived on Earth; ancient environments
	geochemistry	Earth's composition and the processes that change it
Oceanography	physical oceanography	physical characteristics of oceans, such as salinity, waves, and currents
	marine geology	geologic features of the ocean floor, including plate tectonics of the ocean
Environmental science	environmental soil science	interactions between humans and the soil, such as the impact of farming practices; effects of pollution on soil, plants, and groundwater
	environmental chemistry	chemical alterations to the environment through pollution and natural means

FOLDABLES

Incorporate information from this section into your Foldable.

VOCABULARY**SCIENCE USAGE V. COMMON USAGE****Crust**

Science usage: the thin, rocky, outer layer of Earth

Common usage: the hardened exterior or surface part of bread

Earth's Systems

Scientists who study Earth have identified four main Earth systems: the geosphere, atmosphere, hydrosphere, and biosphere. Each system is unique, yet each interacts with the others.

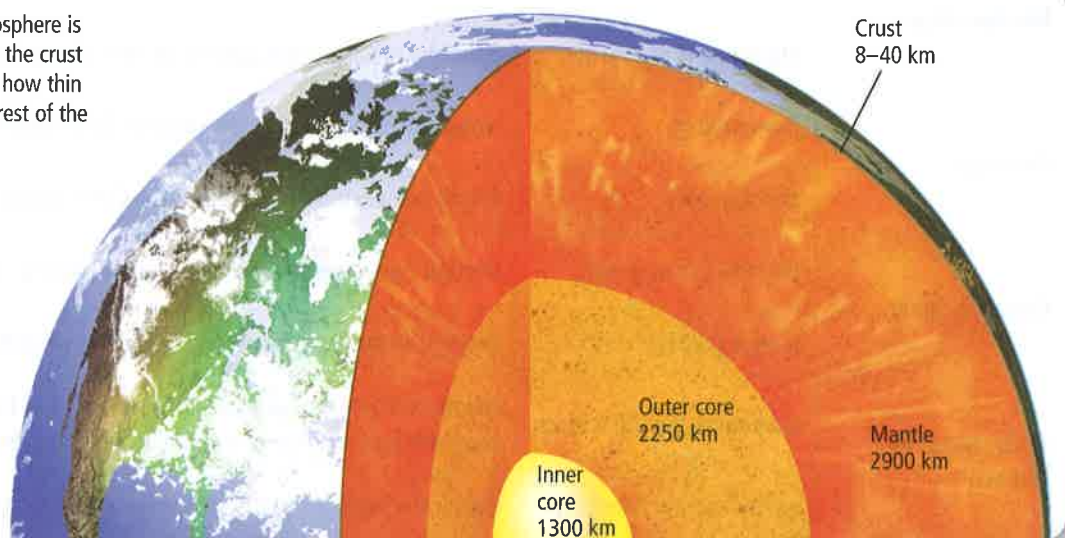
Geosphere The area from the surface of Earth down to its center is called the **geosphere**. The geosphere is divided into three main parts: the crust, mantle, and core. These three parts are illustrated in **Figure 1.3**.

The rigid outer shell of Earth is called the crust. There are two kinds of crust—continental crust and oceanic crust. Just below the crust is Earth's mantle. The mantle differs from the crust both in composition and behavior. The mantle ranges in temperature from 100°C to 4000°C—much warmer than the temperatures found in Earth's crust. Below the mantle is Earth's core. You will learn more about the crust, mantle, and core in Unit 5.

Atmosphere The blanket of gases that surrounds our planet is called the **atmosphere**. Earth's atmosphere contains about 78 percent nitrogen and 21 percent oxygen. The remaining 1 percent of gases in the atmosphere include water vapor, argon, carbon dioxide, and other trace gases. Earth's atmosphere provides oxygen for living things, protects Earth's inhabitants from harmful radiation from the Sun, and helps to keep the planet at a temperature suitable for life. You will learn more about Earth's atmosphere and how parts of this system interact to produce weather in Unit 4.

Hydrosphere All the water on Earth, including the water in the atmosphere, makes up the **hydrosphere**. About 97 percent of Earth's water exists as salt water, while the remaining 3 percent is freshwater contained in glaciers, lakes and rivers, and beneath Earth's surface as groundwater. Only a fraction of Earth's total amount of freshwater is in lakes and rivers. You will find out more about Earth's hydrosphere in Units 3, 4, and 7.

■ **Figure 1.3** Earth's geosphere is composed of everything from the crust to the center of Earth. Notice how thin the crust is in relation to the rest of the geosphere's components.



Biosphere The **biosphere** includes all organisms on Earth as well as the environments in which they live. Most organisms live within a few meters of Earth's surface, but some exist deep beneath the ocean's surface, and others live high atop Earth's mountains. All of Earth's life-forms require interaction with at least one of the other systems for their survival.

As illustrated in **Figure 1.4**, Earth's biosphere, geosphere, hydrosphere, and atmosphere are interdependent systems. For example, Earth's present atmosphere formed millions of years ago through interactions with the geosphere, hydrosphere, and biosphere. Organisms in the biosphere, including humans, continue to change the atmosphere through their activities and natural processes. You will explore interactions among Earth's biosphere and other systems in Units 3, 4, 6, and 7.

Technology

The study of science, including Earth science, has led to many discoveries that have been applied to solve society's needs and problems. The application of scientific discoveries is called technology. Technology is transferable, which means that it can be applied to new situations. Freeze-dried foods, ski goggles, and the ultralight materials used to make many pieces of sports equipment were created from technologies used in our space program. Technology is not used only to make life easier. It can also make life safer. Most people have smoke detectors in their houses to help warn them if there is a fire. Smoke detectors were also invented as part of the space program and were adapted for use in everyday life.

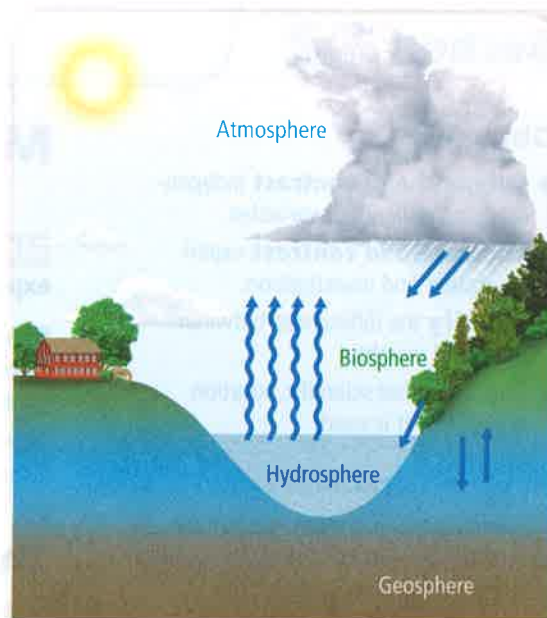


Figure 1.4 All of Earth's systems are interdependent. Notice how water from the hydrosphere enters the atmosphere, falls on the biosphere, and soaks into the geosphere.

Section 1.1 Assessment

Section Summary

- ▶ Earth is divided into four systems: the geosphere, hydrosphere, atmosphere, and biosphere.
- ▶ Earth systems are all interdependent.
- ▶ Identifying the interrelationships between Earth systems leads to specialties and subspecialties.
- ▶ Technology is important, not only in science, but in everyday life.
- ▶ Earth science has contributed to the development of many items used in everyday life.

Understand Main Ideas

1. **Explain** why it is helpful to identify specialties and subspecialties of Earth science.
2. **Apply** What are three items you use on a daily basis that have come from research in Earth science?
3. **Compare and contrast** Earth's geology and geosphere.
4. **Hypothesize** about human impact on each of Earth's systems.
5. **Compare and contrast** the hydrosphere and biosphere.

Think Critically

6. **Predict** what would happen if the makeup of the hydrosphere changed. What would happen if the atmosphere changed?

WRITING in Earth Science

7. Research a subspecialty of Earth science. Make a brochure about a career in this field.

Section 1.2

Objectives

- ▶ **Compare and contrast** independent and dependent variables.
- ▶ **Compare and contrast** experimentation and investigation.
- ▶ **Identify** the differences between mass and weight.
- ▶ **Explain** what scientific notation is and how it is used.

Review Vocabulary

experiment: procedure performed in a controlled setting to test a hypothesis and collect precise data

New Vocabulary

scientific methods

hypothesis

independent variable

dependent variable

control

Le Système International d'Unités (SI)

scientific notation

Methods of Scientists

MAIN Idea Scientists use scientific methods to structure their experiments and investigations.

Real-World Reading Link Have you ever seen a distinct rock formation and wondered how it formed? Have you ever wondered why the soil near your home might be different from the soil in your schoolyard? If so, you have already begun to think like a scientist. Scientists often ask questions and make observations to begin their investigations.

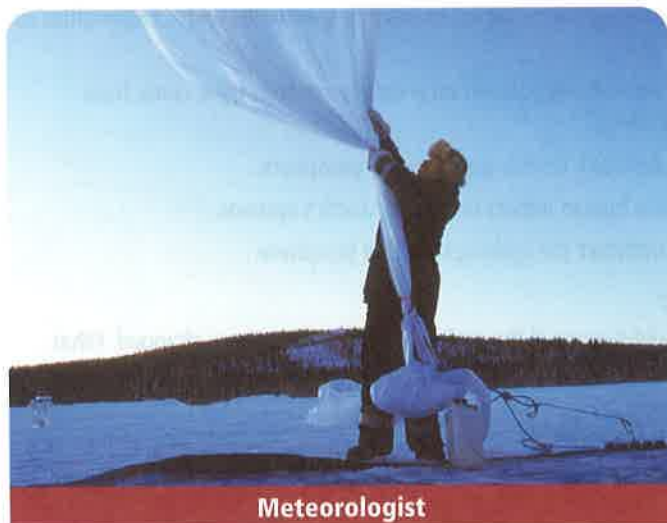
The Nature of Scientific Investigations

Scientists work in many different places to gather data. Some work in the field, and some work in a lab, as shown in **Figure 1.5**. No matter where they work, they all use similar methods to gather data and communicate information. These methods are referred to as scientific methods. As illustrated in **Figure 1.6**, **scientific methods** are a series of problem-solving procedures that help scientists conduct experiments.

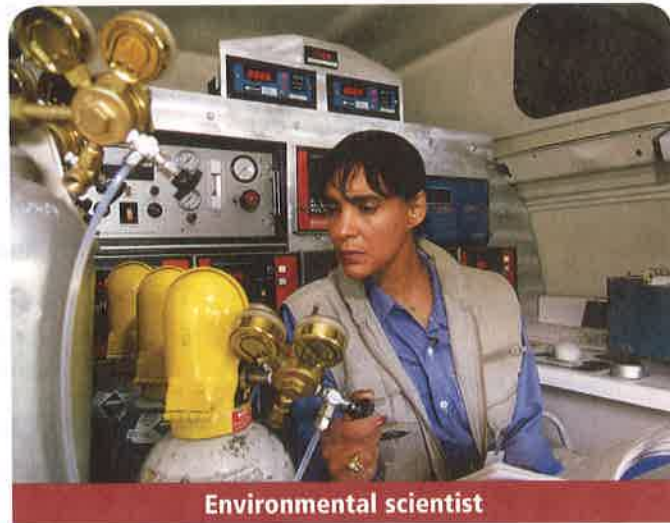
Whatever problem a scientist chooses to pursue, he or she must gather background information on the topic. Once the problem is defined and the background research is complete, a hypothesis is made. A **hypothesis** is a testable explanation of a situation that can be supported or disproved by careful procedures.

It is important to note that scientific methods are not rigid, step-by-step outlines to solve problems. Scientists can take many different approaches to performing a scientific investigation. In many scientific investigations, for example, scientists form a new hypothesis after observing unexpected results. A researcher might modify a procedure, or change the control mechanism. And a natural phenomenon might change the direction of the investigation.

■ **Figure 1.5** Whether a meteorologist gathers storm data in the field or an environmental scientist analyzes microbial growth in a lab, scientific methods provide an approach to problem-solving and investigation.



Meteorologist

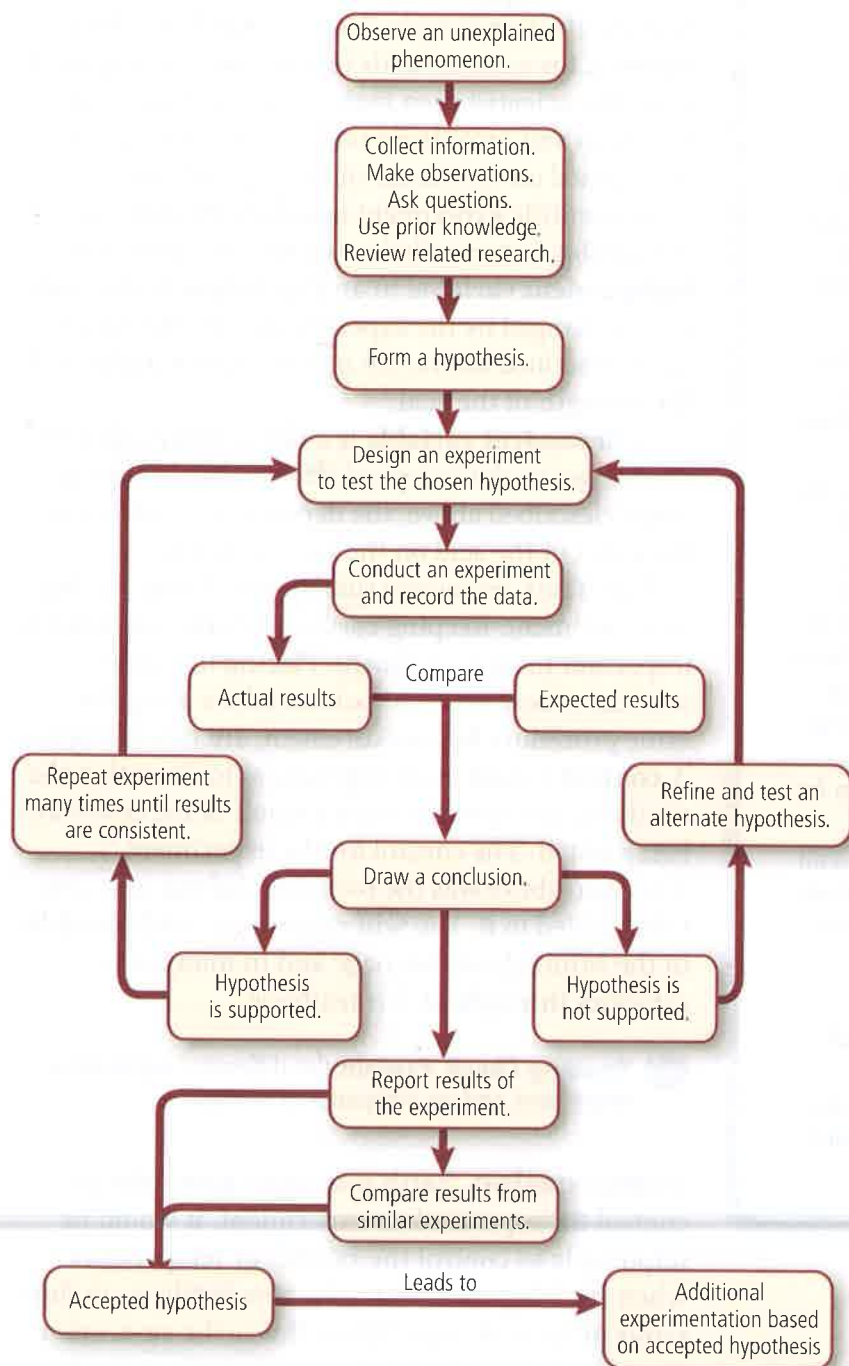


Environmental scientist

Visualizing Scientific Methods



Figure 1.6 Scientific methods are used by scientists to help organize and plan their experiments and investigations. The flow chart below outlines some of the methods commonly used by scientists.



MiniLab

Determine the Relationship Between Variables

How do the rates of heat absorption and release vary between soil and water?

Different substances absorb and release heat at different rates.

Procedure

1. Read and complete the lab safety form.
2. Read the procedure and create a data table to record your temperature results.
3. Pour **soil** into **one container** until it is half full. Pour **water** into a **second container** until it is half full. Leave a **third container** empty.
4. Place **one thermometer** in the soil so that the bulb is barely covered. Use **masking tape** to secure **another thermometer** about 1 cm above the top of the soil.
5. Repeat Step 4 for the container with water.
6. In the empty container, place the bulb of one thermometer halfway into the cup and secure it with masking tape. Use the tape to secure another thermometer bulb about 2 cm higher than the first thermometer bulb.
7. Put the containers on a **sunny windowsill**. Record the temperature shown on each thermometer. Write these values in a table. Record temperature readings every 5 min for 30 min.
8. Remove the containers from the windowsill and continue to record the temperature on each thermometer every 5 min for 30 min.

Analysis

1. **Determine** Which substance absorbed heat more quickly? Which substance lost heat more quickly?
2. **Specify** What was your independent variable? What was your dependent variable?
3. **Identify** your control.

Experimentation An experiment is classified as an organized procedure that involves making observations and measurements to test a hypothesis. Collecting good qualitative and quantitative data is vital to the success of an experiment.

Imagine a scientist is conducting an experiment on the effects of acid on the weathering of rocks. In this experiment, there are three different samples of identical rock pieces. The scientist does not add anything to the first sample. To the second and third samples, the scientist adds two different strengths of acid. The scientist then makes observations (qualitative data) and records measurements (quantitative data) based on the results of the experiment.

A scientific experiment usually tests only one changeable factor, called a variable, at a time. The **independent variable** in an experiment is the factor that is changed by the experimenter. In the experiment described above, the independent variable was the strength of the acid.

A **dependent variable** is a factor that is affected by changes in the independent variable. In the experiment described above, the dependent variable was the effect of the acid on the rock samples.

Constants are factors that do not change during an experiment. Keeping certain variables constant is important to an experiment. Placing the same amount of acid on each rock tested, or using the same procedure for measurement, are two examples. A **control** is used in an experiment to show that the results of an experiment are a result of the condition being tested. The control for the experiment described above was the rock that did not have anything added to it. You will experiment with variables in the MiniLab on this page and in many other activities throughout this textbook.



Reading Check Explain the difference between a dependent and an independent variable.

Investigation Earth scientists cannot always control the aspects of an experiment. It would be impossible to control the rainfall or temperature when studying the effects of a new fertilizer on thousands of acres of corn. When this is the case, scientists refer to their research as an investigation. An investigation involves observation and collecting data but does not include a control. Investigations can often lead scientists to design future experiments based on the observations they have made.

Safety Many of the experiments and investigations in this book will require that you handle various materials and equipment. When conducting any scientific investigation, it is important to use all materials and equipment only as instructed. Refer to the *Reference Handbook* for additional safety information and a table of safety symbols.

Analysis and conclusions New ideas in science are carefully examined by the scientist who made the initial discovery and by other scientists in the same field. Processes, data, and conclusions must be examined to eliminate influence by expectations or beliefs, which is called bias. During a scientific experiment, all data are carefully recorded. Once an experiment is complete, graphs, tables, and charts are commonly used to display data. These data are then analyzed so that a conclusion can be drawn. Many times, a conclusion does not support the original hypothesis. In such a case, the hypothesis must be reevaluated and further research must be conducted.

Measurement

Scientific investigations often involve making measurements. A measurement includes both a number and a unit of measure. Scientific investigations use a standard system of units called **Le Système International d'Unités** (SI), which is a modern version of the metric system. SI is based on a decimal system that uses the number 10 as the base unit. See **Table 1.2** for information on SI and metric units of measure commonly used in science.

Length The standard SI unit to measure length is the meter (m). The distance from a doorknob to the floor is about 1 m. The meter is divided into 100 equal parts called centimeters (cm). Thus, 1 cm is 1/100 of 1 m. One millimeter (mm) is smaller than 1 cm. There are 10 mm in 1 cm. Longer distances are measured in kilometers (km). There are 1000 m in 1 km.

VOCABULARY

ACADEMIC VOCABULARY

Bias

to influence in a particular, typically unfair, direction; prejudice
Their choice of teammates showed a bias toward their friends.

Table 1.2	Measurement and Units
Measurement	SI and Metric Units Commonly Used in Science
Length	millimeter (mm), centimeter (cm), meter (m), kilometer (km)
Mass	gram (g), kilogram (kg), metric ton
Area	square meter (m ²), square centimeter (cm ²)*
Volume	cubic meter (m ³)*, milliliter (mL), liter (L) #
Density	grams per cubic centimeter (g/cm ³)*, grams per milliliter (g/mL)#, kilograms per cubic meter (kg/m ³)*
Time	second (s), hour (h)#
Temperature	kelvin (K)

* units derived from SI units # commonly used metric units

Mass The amount of matter in an object is called mass. Mass depends on the number and types of atoms that make up the object. The mass of an object is the same no matter where the object is located in the universe. The SI unit of mass is the kilogram (kg).

Weight Weight is a measure of the gravitational force on an object. Weight is typically measured with some type of scale. Unlike mass, weight varies with location. For example, the weight of an astronaut while on the Moon is about one-sixth the astronaut's weight on Earth. This is because the gravitational force exerted by the Moon on the astronaut is one-sixth the force exerted by Earth on the astronaut. Weight is a force, and the SI unit for force is the newton (N). A 2-L bottle of soft drink with a mass of 2 kg weighs about 20 N on Earth.



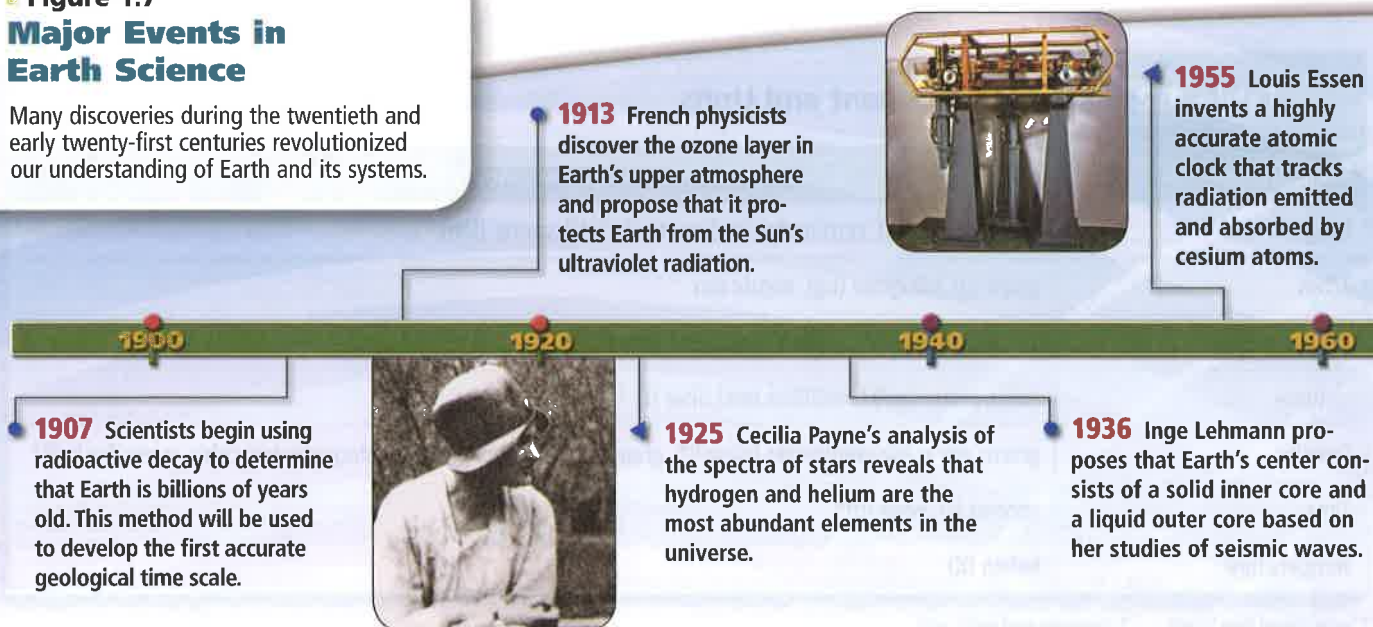
Reading Check Compare mass and weight.

Area and volume Some measurements, such as area, require a combination of SI units. Area is the amount of surface included within a set of boundaries and is expressed in square units of length, such as square meters (m^2).

The amount of space occupied by an object is the object's volume. The SI units for volume, like those for area, are derived from the SI units used to measure length. The basic SI unit of volume for a solid object is the cubic meter (m^3). Measurements for fluid volumes are usually made in milliliters (mL) or liters (L). Liters and milliliters are metric units that are commonly used to measure liquid volumes. Volume can also be expressed in cubic centimeters (cm^3)—1 cm^3 equals 1 mL.

Figure 1.7 Major Events in Earth Science

Many discoveries during the twentieth and early twenty-first centuries revolutionized our understanding of Earth and its systems.



Density The measure of the amount of matter that occupies a given space is density. Density is calculated by dividing the mass of the matter by its volume. Density is often expressed in grams per cubic centimeter (g/cm^3), grams per milliliter (g/mL), or kilograms per cubic meter (kg/m^3).

Time The interval between two events is time. The SI unit of time is the second. In the activities in this book, you will generally measure time in seconds or minutes. Time is usually measured with a watch or clock. The atomic clock provides the most precise measure of time currently known. Known as UTC, Coordinated Universal Time is based on the atomic clock element cesium-133 and is adapted to the astronomical demarcation of day and night. See **Figure 1.7** for more information on the invention of the atomic clock and other advances in Earth science.

Temperature A measure of the average kinetic energy of the particles that make up a material is called temperature. A mass made up of particles that vibrate quickly generally has a higher temperature than a mass whose particles vibrate more slowly. Temperature is measured in degrees with a thermometer. Scientists often measure temperature using the Celsius ($^{\circ}\text{C}$) scale. On the Celsius scale, a comfortable room temperature is about 21°C , and the normal temperature of the human body is about 37°C .

The SI unit for temperature is the kelvin (K). The coldest possible temperature, absolute zero, was established as 0 K or -273°C . Since both temperature units are the same size, the difference between the two scales (273) is used to convert from one scale to another. For example, the temperature of the human body is 37°C , to which you would add 273 to get 310 K.

VOCABULARY

ACADEMIC VOCABULARY

Interval

space of time between two events or states

The interval for pendulum swings was three seconds.

1962 Harry Hess's seafloor spreading hypothesis, along with the discoveries made about the ocean floor, lays the foundation for plate tectonic theory.

1979–1980 *Magsat*, a NASA satellite, takes the first global measurement of Earth's magnetic field.

2004 A sediment core retrieved from the ocean floor discloses 55 million years of Earth's atmospheric and climatic history. The sample reveals that the north pole once had a warm climate.

1970

1980

1990

2000

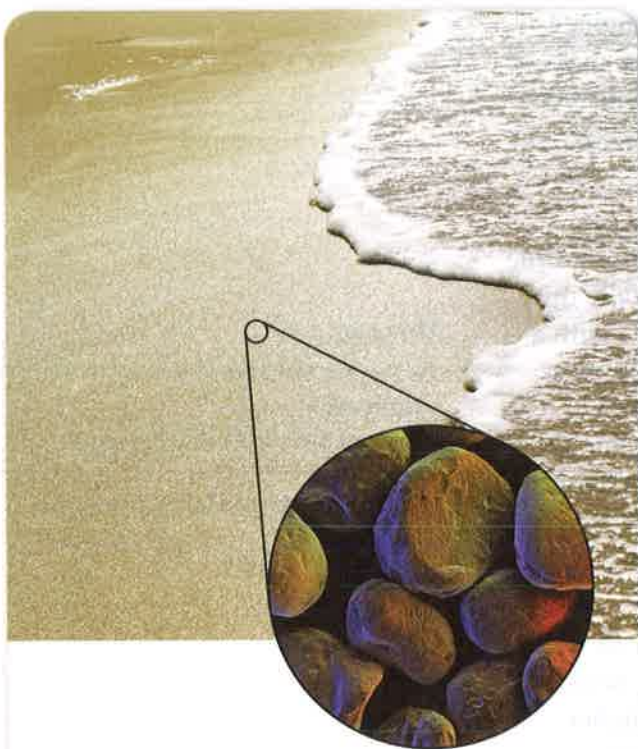
2010

1970 George Carruthers' ultraviolet camera and spectrograph, placed on the Moon's surface, analyzes pollutants in Earth's atmosphere and detects interstellar hydrogen.



1990 The *Hubble Space Telescope* goes into orbit, exploring Earth's solar system, measuring the expansion of the universe, and providing evidence of black holes.

Concepts in Motion
Interactive Time Line To learn more about these discoveries and others, visit glencoe.com. **Earth Science online**



✱ **Figure 1.8** On a 5-km-long beach, such as the one shown above, there might be 8×10^{15} grains of sand. The average size of a grain of sand is 0.5 mm.

Scientific Notation

In many branches of science, some numbers are very small, while others are very large. To express these numbers conveniently, scientists use a type of shorthand called **scientific notation**, in which a number is expressed as a value between 1 and 10 multiplied by a power of 10. The power of 10 is the number of places the decimal point must be shifted so that only a single digit remains to the left of the decimal point.

If the decimal point must be shifted to the left, the exponent of 10 is positive. **Figure 1.8** shows a beach covered in sand. The number of grains of sand on Earth has been estimated to be approximately 4,000,000,000,000,000,000. In scientific notation, this number is written as 4×10^{21} .

In astronomy, masses and distances are usually so large that writing out the numbers would be cumbersome. For example, the mass of Earth at 5,974,200,000,000,000,000,000 kg would be written as 5.9742×10^{24} kg in scientific notation.

If the decimal point in a number must be shifted to the right, the exponent of 10 is negative. The diameter of an atom in meters, for example, which is approximately 0.0000000001 m, is written as 1×10^{-10} m.

Section 1.2 Assessment

Section Summary

- Scientists work in many ways to gather data.
- A good scientific experiment includes an independent variable, dependent variable, and control. An investigation, however, does not include a control.
- Graphs, tables, and charts are three common ways to communicate data from an experiment.
- SI, a modern version of the metric system, is a standard form of measurement that all scientists can use.
- To express very large or very small numbers, scientists use scientific notation.

Understand Main Ideas

1. **MAIN Idea** Explain why scientific methods are important and why there is not one established way to conduct an investigation.
2. **Compare and contrast** the purpose of a control, an independent variable, and a dependent variable in an experiment.
3. **Calculate** Express 0.00049386 in scientific notation.
4. **Calculate** Convert the temperature 49°C to kelvin.
5. **Compare and contrast** volume and density.

Think Critically

6. **Construct** a plan to test the absorption of three different kinds of paper towels, including a control, dependent variable, and independent variable.
7. **Explain** which is more useful when comparing mass and weight on different planets.

MATH in Earth Science

8. If you have 20 mL of water, how many cubic centimeters of water do you have?

Section 1.3

Objectives

- **Explain** why precise communication is crucial in science.
- **Compare and contrast** scientific theories and scientific laws.
- **Identify** when it is appropriate to use a graph or a model.

Review Vocabulary

hypothesis: testable explanation of a situation

New Vocabulary

scientific model
scientific theory
scientific law

Communication in Science

MAIN Idea Precise communication is crucial for scientists to share their results effectively with each other and with society.

Real-World Reading Link If you read an advertisement for a product called “Glag” without any description, would you know whether to eat it or wear it? When a scientist does an investigation, he or she has to describe every part of it precisely so that everyone can understand his or her conclusions.

Communicating Results

There are many ways to communicate information, such as newspapers, magazines, TV, the Internet, and scientific journals. Think back to the Launch Lab from the beginning of the chapter.

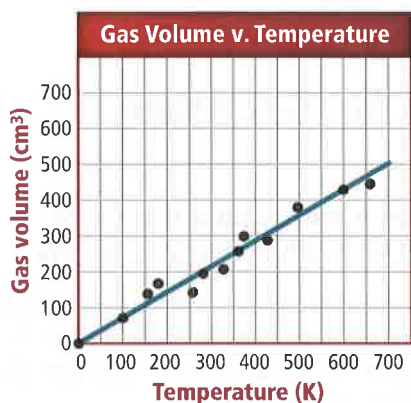
Although you and your lab partner both used the same form of communication, were your descriptions identical? Scientists have the responsibility to truthfully and accurately report their methods and results. To keep them ethical, a system of peer review is used in which scientists in the same field verify each other’s results and examine procedures and conclusions for bias. Communicating scientific data and results, as the scientists are shown doing in **Figure 1.9**, also allows others to learn of new discoveries and conduct new investigations that build on previous investigations.

Lab reports Throughout this book, you will conduct many Earth science investigations and experiments. During and after each, you will be asked to record and analyze the information that you collected and to draw conclusions based on your data. Your written account of each lab is your lab report. This will be used by your teacher to assess your understanding. You might also be asked to compare your results with those of other students to help you find both similarities and differences among the results.

■ **Figure 1.9** Scientists, like those shown in the photo, communicate data and discoveries with each other to maintain accuracy in methods and reporting.

Infer what could happen if scientists did not compare results.





■ **Figure 1.10** A line graph shows the relationship between two variables.

Determine Based on this graph, what is the relationship between gas volume and temperature?

Graphs By graphing data in a variety of ways, scientists can more easily show the relationships among data sets. Graphs also allow scientists to represent trends in their data. You will be asked to graph the results of many experiments and activities in this book. There are three types of graphs you will use in this book.

Line graphs A visual display that shows how two variables are related is called a line graph. As shown in **Figure 1.10**, on a line graph, the independent variable is plotted on the horizontal (x) axis, and the dependent variable is plotted on the vertical (y) axis.

Circle graphs To show a fixed quantity, scientists often use a circle graph, also called a pie graph. The circle represents the total and the slices represent the different parts of the whole. The slices are usually presented as percentages.

Bar graphs To represent quantitative data, bar graphs use rectangular blocks called bars. The length of the bar is determined by the amount of the variable you are measuring as well as the scale of the bar graph. See the *Skillbuilder Handbook*, page 951, for examples of all the types of graphs described above.

Models In some of the investigations, you will be making and using models. A **scientific model** is an idea picture, a system, or a mathematical expression that represents the concept being explained. While a model might not have all of the components of a given idea, it should be a fairly accurate representation.

DATA ANALYSIS LAB

Based on Real Data*

Make and Use Graphs

How can graphs help interpret data? The table shows the average surface temperature of Earth over the past 125 years. The data in the table are global, average surface temperatures, in kelvin, starting in the year 1880.

Think Critically

1. **Construct** a line graph from the average surface temperatures in the data table.
2. **Convert** each temperature from kelvin to degrees Celsius by subtracting 273 from each value. Place both on your graph.
3. **Determine** from your graph the average surface temperature for 1988 in degrees Celsius.
4. **Extrapolate**, in Celsius, what the average surface temperature will be in the year 2100 if this trend continues.

Data and Observations

Average Global Surface Temperatures	
Years	Average surface temperature (K)
1880–1899	286.76
1900–1919	286.77
1920–1939	286.97
1940–1959	287.02
1960–1979	286.98
1980–1999	287.33
2000–2004	287.59

*Data obtained from Goddard Institute for Space Studies, NASA Goddard Space Flight Center

Models can change when more data are gathered. As shown in **Figure 1.11**, early astronomers thought that Earth was the center of the solar system. This model was changed as the result of observations of the motions of the Sun and the planets in the night sky. The observations showed that the planets in our solar system orbit the Sun.

Theories and Laws

A **scientific theory** is an explanation based on many observations during repeated investigations. A scientific theory is valid only if it is consistent with observations, makes predictions that can be tested, and is the simplest explanation of observations. Like a scientific model, a theory can be changed or modified with the discovery of new data.

A **scientific law** is a principle that describes the behavior of a natural phenomenon. A scientific law can be thought of as a rule of nature, even though the cause of the law might not be known. The events described by a law are observed to be the same every time. An example of a scientific law is Newton's first law of motion, which states that an object at rest or in motion stays at rest or in motion unless it is acted on by an outside force. This law explains why Earth and other planets in our solar system remain in orbit around the Sun. Theories are often used to explain scientific laws.

In this book, you will communicate your observations and draw conclusions based on scientific data. You will also read that many of the models, theories, and laws used by Earth scientists to explain various processes and phenomena grow from the work of other scientists and sometimes develop from unexpected discoveries.



Figure 1.11 Scientific models, like this ancient one of the solar system, are used to represent a larger idea or system. As scientists gather new information, models can change or be revised. **Explain** what is wrong with this model.

Section 1.3 Assessment

Section Summary

- Scientists communicate data so others can learn the results, verify the results, examine conclusions for bias, and conduct new experiments.
- There are three main types of graphs scientists use to represent data: line graphs, circle graphs, and bar graphs.
- A scientific model is an accurate representation of an idea or theory.
- Scientific theories and scientific laws are sometimes discovered accidentally.

Understand Main Ideas

1. **MAIN Idea** **Explain** what might happen if a scientist inaccurately reported data from his or her experiment.
2. **Describe** the difference between scientific theory and scientific law.
3. **Apply** Why is it important to compare your data from a lab with that of your classmates?

Think Critically

4. **Interpret** Why would a model be important when studying the solar system?
5. **Explain** when to use a line graph, a circle graph, and a bar graph.

WRITING in Earth Science

6. Research scientific laws and theories, and write a concise example of each.

ON SITE: IN THE FOOTSTEPS OF DISASTER

On December 26, 2004, a massive earthquake rattled the seafloor of the Indian Ocean. A tsunami was generated by the earthquake, which devastated the landscape and killed almost 300,000 people in 12 countries. After humanitarian efforts were underway, many Earth scientists mobilized to collect data before the area was changed by cleanup efforts.

Planning the investigation Jose Borrero, an environmental engineer at University of Southern California, wanted to determine the height of the waves associated with the tsunami, how far inland they traveled, the number of waves, and the distance between them. This information would determine where to rebuild towns and assist in the development of a warning system and a hazard plan.

Taking measurements To measure heights of the waves and the following rush of water, Borrero looked for mud or watermarks on the buildings that were left standing. He then placed a 5-m pole next to the watermark to measure the height the water reached. The closer he got to the coast, however, the less he was able to measure accurately. The water had surged up over 5 m deep, so he relied on visual estimates and photos for documentation. With each measurement, he recorded the location on the Global Positioning Satellite system (GPS).



The tsunami destroyed many homes and buildings, leaving few of the structures standing.

After a six-day study of the devastation, Borrero had more than 150 data points. Upon returning to the United States, scientists used these data to determine that the waves reached 15–30 m high in Banda Aceh, and almost 3.2 km inland.

Using models It is impossible and unethical to simulate natural disasters on an actual scale, so scientists use the data collected from real incidents to create models of those events to learn more about how nature behaves. Using scientific methods and data gathered, scientists are able to provide information for model building or computer simulation. Back at the lab, Borrero applies the data to study other possible tsunami scenarios. He uses data to predict wave height and the area of inundation along the coast, should a tsunami hit the United States.

He hopes that the data collected will enable better detection and prevent widespread devastation from a natural tsunami disaster.

WRITING in Earth Science

Journal Imagine you are a geologist who is accompanying a team of scientists to a natural disaster. Describe the way you will use the scientific method to gather data for your report. Visit glencoe.com to learn more about scientific methods in the field.

GEO LAB

MEASUREMENT AND SI UNITS

Background: Suppose someone asked you to measure the area of your classroom in square cubits. What would you use? A cubit is an ancient unit of length equal to the distance from the elbow to the tip of the middle finger. Today, SI is used as a standard system of measurement.

Question: Why are standard units of measure important?

Materials

water
large graduated cylinder or beaker
graph paper
balance
pieces of string
spring scale
rock samples
ruler

Safety Precautions

Procedure

1. Read and complete the lab safety form.
2. Obtain a set of rock samples from your teacher.
3. Measure the weight and length of two rock samples using a nonstandard unit of measure. You might use your pinky, a paper clip, or anything you choose.
4. Record your measurements.
5. Working with a partner, explain your units of measure and which samples you measured. Ask your partner to measure the rocks using your units.
6. Record your partner's measurements.
7. Use the information in the *Skillbuilder Handbook* to design a data table in which to record the following measurements for each rock sample: area, volume, mass, weight, and density.
8. Carefully trace the outline of each rock onto a piece of graph paper. Determine the area of each sample and record the values in your data table.
9. Secure each rock with a piece of dry string. Place the string loop over the hook of the spring scale to determine the weight of each rock sample. Record the values in your data table.
10. Pour water into a large graduated cylinder until it is half full. Record this volume in the table. Slowly lower the sample by its string into the cylinder. Record the volume of the water. Subtract the two values to determine the volume of the rock sample.
11. Repeat Steps 9 and 10 for each rock. Make sure the original volume of water for each rock is the same as when you measured your first sample.
12. Follow your teacher's instructions about how to use the balance to determine the mass of each rock. Record the measurements in your table.

Analyze and Conclude

1. **Interpret** How did the results of your initial measurements (Step 4) compare with your lab partner's (Step 6)? If they were different, why were they?
2. **Propose** What does this tell you about the importance of standard units of measure?
3. **Compare** the area of each of your samples with the volumes determined for the same rock. Which method of measurement was more accurate? Explain.
4. **Calculate** the density of each sample using this formula: $\text{density} = \text{mass}/\text{volume}$. Record these values in your data table.
5. **Explain** Does mass depend on the size or shape of a rock? Explain.
6. **Identify** the variables you used to determine the volume of each sample.
7. **List** the standard units you used in this investigation and explain the standard unit advantages over your measurement units.

INQUIRY EXTENSION

Inquiry How could you find the volume of a rock, such as pumice, that floats in water? Design an investigation to test your prediction.



BIG Idea Earth scientists use specific methods to investigate Earth and beyond.

Vocabulary

Key Concepts

Section 1.1 Earth Science

- astronomy (p. 6)
- atmosphere (p. 8)
- biosphere (p. 9)
- environmental science (p. 7)
- geology (p. 7)
- geosphere (p. 8)
- hydrosphere (p. 8)
- meteorology (p. 6)
- oceanography (p. 7)

- MAIN Idea** Earth science encompasses five areas of study: astronomy, meteorology, geology, oceanography, and environmental science.
- Earth is divided into four systems: the geosphere, hydrosphere, atmosphere, and biosphere.
 - Earth systems are all interdependent.
 - Identifying the interrelationships between Earth systems leads to specialties and subspecialties.
 - Technology is important, not only in science, but in everyday life.
 - Earth science has contributed to the development of many items used in everyday life.

Section 1.2 Methods of Scientists

- control (p. 12)
- dependent variable (p. 12)
- hypothesis (p. 10)
- independent variable (p. 12)
- Le Système International d'Unités (SI) (p. 13)
- scientific methods (p. 10)
- scientific notation (p. 16)

- MAIN Idea** Scientists use scientific methods to structure their experiments and investigations.
- Scientists work in many ways to gather data.
 - A good scientific experiment includes an independent variable, dependent variable, and control. An investigation, however, does not include a control.
 - Graphs, tables, and charts are three common ways to communicate data from an experiment.
 - SI, a modern version of the metric system, is a standard form of measurement that all scientists can use.
 - To express very large or very small numbers, scientists use scientific notation.

Section 1.3 Communication in Science

- scientific law (p. 19)
- scientific model (p. 18)
- scientific theory (p. 19)

- MAIN Idea** Precise communication is crucial for scientists to share their results effectively with each other and with society.
- Scientists communicate data so others can learn the results, verify the results, examine conclusions for bias, and conduct new experiments.
 - There are three main types of graphs scientists use to represent data: line graphs, circle graphs, and bar graphs.
 - A scientific model is an accurate representation of an idea or theory.
 - Scientific theories and scientific laws are sometimes discovered accidentally.

Vocabulary Review

Explain the relationship between the vocabulary terms below.

1. geosphere, mantle
2. hydrosphere, atmosphere
3. oceanography, hydrosphere
4. meteorology, atmosphere
5. geology, biosphere

For Questions 6 to 9, fill in the blanks with the correct vocabulary terms from the Study Guide.

6. When conducting experiments, scientists use _____ to help guide their processes.
7. The _____ is the one factor that can be manipulated by the experimenter.
8. Scientists use a form of shorthand called _____ to express very large or very small numbers.
9. Most scientific studies and experiments use a standard system of units called _____.

Write a sentence using the following vocabulary terms.

10. scientific theory
11. scientific law
12. scientific model

Fill in the blanks with a vocabulary term from the Study Guide.

13. In the field of _____, scientists measure temperature, pressure, and humidity.
14. Their measurements come from features of the _____ and hydrosphere, and they look at how weather affects the _____ and geosphere.
15. The units of their measurements come from _____ and the metric system.
16. The numbers generally are not large, so _____ is not used.

Understand Key Concepts

17. Which one of these is NOT a specialized area of Earth science?
 - A. astronomy
 - B. environmental science
 - C. technology
 - D. oceanography

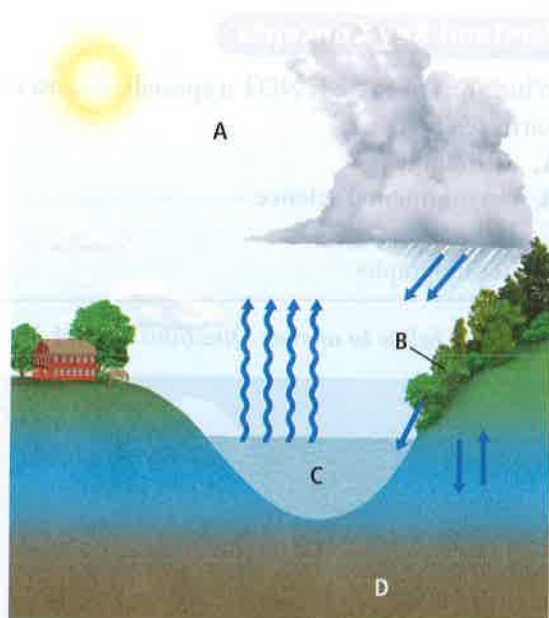
Use the figure below to answer Questions 18 and 19.



18. Which type of scientist is shown above?
 - A. oceanographer
 - B. geologist
 - C. astronomer
 - D. meteorologist
19. Which type of research is this scientist conducting?
 - A. field research
 - B. lab research
 - C. library research
 - D. biological research
20. Which is a sequence of steps a scientist might use to conduct an investigation?
 - A. analysis, test, question, conclude
 - B. test, question, conclude, analysis
 - C. question, test, analysis, conclude
 - D. conclude, test, question, analysis

Chapter 1 Assessment

Use the figure below to answer Questions 21 and 22.



21. Identify the Earth system that is labeled A.
 - A. atmosphere
 - B. biosphere
 - C. hydrosphere
 - D. geosphere
22. Identify the Earth system that is labeled B.
 - A. atmosphere
 - B. biosphere
 - C. hydrosphere
 - D. geosphere
23. Which type makes up 97 percent of Earth's water?
 - A. groundwater
 - B. salt water
 - C. freshwater
 - D. spring water
24. Which is true of scientific models?
 - A. They never change.
 - B. They must be true for at least ten years.
 - C. They will be modified with new observations and data.
 - D. They are generally the work of one scientist.
25. Select the correct scientific notation for 150,000,000 km.

A. 150×10^6 km	C. 1.5×10^8 km
B. 15×10^7 km	D. 0.15×10^9 km

Constructed Response

26. **Explain** how technology relates to science.

Use the photo below to answer Question 27.



27. **Identify** the SI units that would be used to measure each of the above items.
28. **Summarize** each of Earth's systems and explain their relationships to each other.
29. **Compare and contrast** an investigation and an experiment.
30. **Apply** Why might a graph be more helpful in explaining data than just writing the results in words?
31. **Apply** When ice is heated above 0°C , it melts. Is this a theory or a law? Explain.

Think Critically

32. **CAREERS IN EARTH SCIENCE** Why would a meteorologist need an understanding of Earth's hydrosphere?
33. **Design an Experiment** Suppose you want to find the effect of sunlight on the temperature of a room with the shade up and the shade down. Describe how you would test this hypothesis. What would be your variables? What would you use as a control?

- 34. Propose** An ecologist wants to study the effects of pollution on plant growth. The scientist uses two groups of plants. To the first group, a type of pollutant is added. To the second group, nothing is added. The scientist records plant growth for each plant for two weeks. What is the purpose of the second group in the scientist's study?

Use the table below to answer Question 35.

Some SI Conversions			
1 m	=	_____ mm	= _____ km
1 g	=	_____ mg	= _____ kg
1 cm ³	=	_____ m ³	= _____ mL
3.5 km	=	_____ m	= _____ cm

- 35. Calculate** Copy the table into your notebook. Complete the table. Once you have made your conversions, express each answer in scientific notation.

Concept Mapping

- 36.** Use the following terms to make a concept map summarizing the units used to measure each quantity discussed in the chapter: *time, density, temperature, volume, mass, weight, length, area, °C, g/mL, km, s, cm³, m², kg, and N*. For help, refer to the *Skillbuilder Handbook*.

Challenge Question

- 37. Evaluate** A scientist is researching a new cancer drug. Fifty patients have been diagnosed with the type of cancer the drug is designed to treat. If a control is used, the patients might not receive any medication. The patients do not know if they are receiving the placebo or the new medication. For this reason, the patients are allowed to also receive traditional treatment if they choose. How will this impact the research? How should the scientist account for this information in the results? Should the scientists be allowed to discourage patients from receiving additional treatment?

Additional Assessment

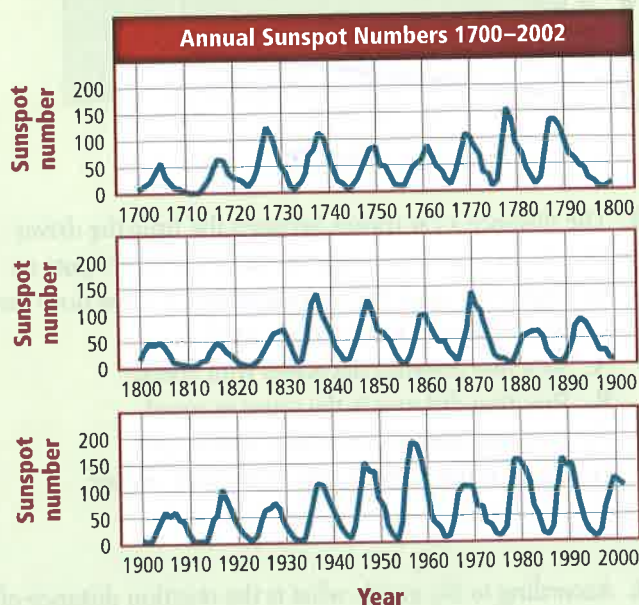
- 38. WRITING in Earth Science** Imagine you are writing an explanation of the scientific methods for someone who has never done a scientific investigation before. Explain what the scientific methods are and why they are so important.



Document-Based Questions

Data obtained from: Annual mean sunspot numbers 1700–2002.
National Geophysical Data Center.

Use the graphs below to answer Questions 39–41.



- 39.** Is there a consistent pattern in the graphs? If so, what is the pattern showing?
- 40.** What do the graphs express regarding the number of sunspots that have been seen and recorded since the 1700s?
- 41.** What would you predict would be the pattern for the years 2000 to 2100?

Cumulative Review

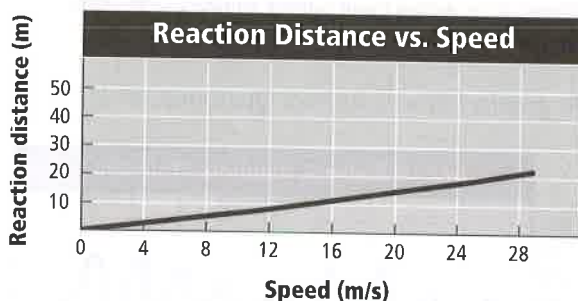
In Chapters 2–30, Cumulative Review questions will help you review and check your understanding of concepts discussed in previous chapters.

Standardized Test Practice

Multiple Choice

1. Identify the type of Earth science that involves the study of the materials that make up Earth.
A. astronomy
B. meteorology
C. geology
D. oceanography

Use the graph below to answer Questions 2 and 3.



2. The distance a car travels between the time the driver decides to stop the car and the time the driver puts on the brakes is called the reaction distance. How does the reaction distance change with speed?
A. Reaction distance decreases with speed.
B. Reaction distance is the same as speed.
C. Reaction distance increases with speed.
D. There is not enough information to answer the question.
3. According to the graph, what is the reaction distance of the driver traveling 20 m/s?
A. 3 m
B. 15 m
C. 20 m
D. 28 m
4. Which lists Earth's layers from the inside out?
A. inner core, outer core, mantle, crust
B. crust, mantle, outer core, inner core
C. crust, inner core, outer core, mantle
D. mantle, outer core, inner core, crust
5. A block is 2 cm wide, 5.4 cm deep, and 3.1 cm long. The density of the block is 8.5 g/cm³. What is the mass of the block?
A. 33.48 g
B. 85.10 g
C. 399.3 g
D. 284.58 g

6. If a conclusion is supported by data, but does not support an original hypothesis, what should a scientist do?
A. The scientist should reevaluate the original hypothesis.
B. The scientist should redesign the experiment.
C. The scientist should not change anything.
D. The scientist should modify the conclusion.

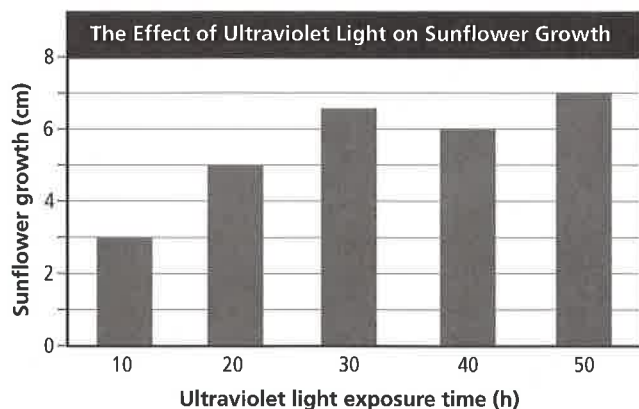
Use the illustration below to answer Questions 7 and 8.



7. This sign was found at the entrance to a chemistry laboratory. Why is this an important sign?
A. Goggles help chemists see better.
B. Chemicals can seriously damage eyes and skin.
C. Accidents rarely happen in laboratories.
D. Chemists will be fined if they do not obey the rules.
8. Why are safety rules posted, like this sign, or stated when conducting experiments?
A. Safety rules are used to scare students.
B. The goal of safety rules is to make an experiment boring.
C. Safety rules are just suggestions as to how to behave during an experiment.
D. The safety rules are given for scientists' protection.
9. What should you always do when conducting an experiment?
A. You should clean up broken glass yourself.
B. You should unplug cords by pulling on the cord, not the plug.
C. You should report spills immediately.
D. You should flush your eyes at the eyewash station.
10. Which of the following are Sir Isaac Newton's ideas on motion considered to be?
A. scientific law
B. scientific theory
C. scientific model
D. hypothesis

Short Answer

Use the graph below to answer Questions 11–13.



- According to the graph, what was the greatest growth observed?
- What type of graph is this? Why is this the best way to represent the data?
- What are some variables that might affect the outcome of the experiment?
- Describe the difference between the terms *astronomy* and *meteorology*.
- Analyze the idea that technology is transferable. How is this beneficial?
- Explain the importance of making a hypothesis before conducting an experiment.
- Justine wants to measure how far an ant moves across a table in 1-min intervals. What would be the independent variable in this example?

Reading for Comprehension

Investigation Steps

Michael conducted an experiment to test if matter is conserved after a phase change. He filled an empty bottle with 50 mL of water and placed it in a sunny window until the liquid water changed to water vapor. The steps of the activity are listed in the table below but might not be in the correct order.

Investigation Steps	
1	Find the mass of the bottle, lid, and water vapor.
2	Pour 50 mL of water into an empty bottle.
3	Find the mass of the bottle, lid, and 50 mL of water.
4	Place a lid on the opening of the bottle to tightly seal it.

- Which shows the investigation steps in the correct order?
 - 1, 2, 3, 4
 - 2, 4, 3, 1
 - 4, 2, 1, 3
 - 2, 4, 1, 3
- According to the text, what scientific idea is Michael testing?
 - the rate of evaporation
 - the conservation of energy
 - the conservation of matter
 - the equilibrium of a system
- Why does Michael put a lid on the bottle?
 - to prevent water vapor from leaving the system
 - to make the water evaporate faster
 - to prevent bacterial growth in the system
 - to establish equilibrium

NEED EXTRA HELP?

If You Missed Question . . .

Review Section . . .

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.1	1.3	1.3	1.1	1.2	1.3	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.1	1.1	1.2	1.2